

**Fermilab Accelerator Advisory Committee
Report of the Meeting of November 17 - 19, 2004**

Committee: John Corlett (LBNL), Georg Hoffstaetter (Cornell), Jean-Pierre Koutchouk (CERN), Stephen Milton (ANL), Michiko Minty (DESY), Steve Peggs (BNL), Lucio Rossi (CERN), Thomas Roser (BNL, Chair)

Apologies: Shin-ichi Kurokawa (KEK), Ronald Ruth (SLAC)

DOE observer: Phil Debenham (DOE)

Assignments:

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|---|------------------------------|
| 1. Electron cooling commissioning | Hoffstaetter, Corlett, Roser |
| 2. NUMI commissioning | Koutchouk, Peggs |
| 3. Superconducting Module Test Facility | Minty, Milton, Rossi |

Introductory Remark

The Committee would like to thank all the presenters for the very interesting and excellently prepared presentations. It has again been a pleasure to learn about the many exciting accelerator physics projects at Fermilab.

General Comments

The Committee would like to congratulate the Run II team for the excellent Tevatron performance. The integrated luminosity of 342 pb^{-1} exceeded the design values for FY2004 and a new record luminosity of over $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ was reached. The Tevatron luminosity has now exceeded the design luminosity of the Main Injector project.

The integrated luminosity goal for the Tevatron for FY2005 was established at 480 pb^{-1} and 370 pb^{-1} for the design and base level, respectively. Even though no major improvements will be operational for the upcoming year these integrated luminosity values seem very reasonable based on last year's performance.

The Committee would like to congratulate also the high field magnet team for the construction and test of a NbSn dipole magnet that has successfully exceeded 10 T, thus confirming the clear understanding and control of flux jump instabilities. Also remarkable is the completion of the super-ferric program, with the successful test and full magnetic validation of the 100 kA compact double aperture magnet, a novel design originally proposed by Fermilab in the context of the VLHC program.

The Committee was presented with the plans for two major commissioning efforts: electron cooling of the antiproton beam in the Recycler and high intensity proton beams from the Main Injector for the neutrino experiment NUMI. The efforts for both commissioning activities are included in the Tevatron operations plans. The Committee believes that both projects are ready for commissioning to begin and that the commissioning activities are well planned. Detailed Committee comments follow below.

The Committee also notes that Fermilab was well prepared for the outcome of the deliberations of the International Technology Recommendation Panel (ITRP) and, when the decision in favor of the cold technology for the International Linear Collider (ILC) was announced, was already prepared with a plan to build a Superconducting Module & Test Facility (SMTF) at Fermilab in a broad collaboration of US institutions, laboratories, and industries. The Committee fully supports the plans for the SMTF to develop and test high gradient superconducting cryo-modules primarily for the International Linear Collider (ILC). Detailed comments on the SMTF follow below.

Commissioning of electron cooling in the Recycler Ring

The projected integrated luminosity for Run II relies strongly on the success of electron cooling in the Recycler ring. It is expected that the luminosity could increase by a factor of 2 to 2.5 if electron cooling can be used efficiently. Therefore, the current installation and a timely commissioning of the electron cooling system are major short-term goals for the Tevatron complex.

All major subsystems of electron cooling have been tested in much detail off-line; all these tests are quite impressive. This includes testing of the Pelletron in its previous 5MV version, testing of the beam transport through the cooling section, and the mapping and testing of the cooling section and the BPM and Schottky diagnostics. Also the progress in relocating, reassembling, and upgrading the system next to the recycler is very impressive. It is clear that the recycler/cooler team is very competent.

Does the strategy appear effective both in terms of achieving these goals and in being consistent with the anticipated allocation of antiprotons and access time within the Run II plan for 2005?

Once the numbers for stability of the recycler and cooler beam, accuracy of the diagnostics, temperatures of the electron beam and IBS rates of the antiprotons are accepted, the commissioning plan seems very reasonable. But there are many steps that have to be taken to verify all these essential parameters. This includes bringing the upgraded Pelletron back into operation as soon as possible and establishing the required stability of the electron current, energy, trajectory, and density.

Since measuring actual beam cooling is very time consuming, it is essential that the computed cooling rates are realistic, and also that antiproton beams with maximal energy spread and 2-3 mm mrad emittances can be produced reliably. While the production of the required beam parameters has been tested, computed cooling rates have never been compared with experiments. The theory is, however, quite similar to IBS theory and the agreement between simulation and experiment there is better than a factor of 2. It is fair to say that the commissioning plan that was presented should work even if the computed cooling rates are wrong by a factor of 2.

Are there any suggestions on mitigation of risks?

The first recommendation is, keep up the good work. Detailed recommendations are:

1. Implement a microscopic simulation of electron cooling. Possibly this can be added to the microscopic simulation of IBS that is under development.

2. The BPM system in the cooling section is absolutely essential to establish overlapping electron and antiproton beams. The system has been tested thoroughly and the demonstrated accuracy seems sufficient. It is important that no systematic errors, such as signal intensity dependencies, have been neglected.
3. The orifice detectors for measuring the beam cross section can be biased by beam distribution variations, and measurements are time-consuming. Since changes in the cross sections are produced by optical mismatches, we advise to investigate methods of minimizing optics errors that do not rely on the orifice detectors. These could be beam based optics measurements that rely only on the BPMs. The orifice measurements would then only be used for fine-tuning.
4. The electron cooling commissioning plan has already been reviewed internally. A plan with technical details for the commissioning period should be presented to another internal review once it has been worked out.
5. The required electron beam parameters and tolerable trajectory error between electrons and antiprotons have been specified. Nevertheless, some parameters, such as the total required current, are not solidly specified. The Committee advises to extend this list in more detail. For example a list of alignment tolerances of individual elements would be more useful than a total allowable field error integral over all of the cooling section. These tolerances could be included in a cooling simulation program. This is important not only to verify that one expects efficient cooling within these tolerances, but also to aid commissioning by providing a computer model of the total cooler system.

Are the goals well defined and credible?

The goal of the commissioning is well defined. It consists of showing indications of electron cooling in the Recycler. The commissioning strategy to achieve this goal seems reasonable. The resources allocated for setup and commissioning of the electron cooler seem reasonable, too. The permission to interrupt the Main Injector operation for 20% of the time seems sufficient and reasonable, given that many tests of the electron cooler can be performed without interruption of the Main Injector. The timeline is not generous, but without major distractions the milestones do seem achievable.

What are the primary technical risks and their potential impacts?

There is a risk that the Pelletron will not perform stably in a timely fashion. It is therefore important to establish stable 0.5A, 4.3MeV operation as soon as possible. Damage due to beam loss can also be important. This subject has already been studied, but it deserves careful and continuous attention.

NuMI Commissioning Plan

General

The Committee heard three excellent presentations overviewing the project status and the NuMI and Main Injector (MI) commissioning plan. It congratulates the NuMI and MI teams for their impressive achievements. The presentations were complemented by a visit to the beam line and target area.

The different components of the NuMI project (beam line, target and horns, decay channel, hadron absorber and muon detector, near and far detectors) appear to be within schedule and

budget. The MI instrumentation (bunch-by-bunch feedback and beam observation) is upgraded with the latest digital techniques to reach the ultimate NuMI performance. The commissioning strategy and plan are well defined.

Are the goals well defined and credible?

The performance goals are well defined and the strategy to reach them appears credible. The Committee expects the CD4 beam requirements (beam intensity of 1×10^{12} ppp) to be met in time and rapidly exceeded. For nominal and ultimate performance (2.5×10^{13} ppp and 4×10^{13} ppp), the impressive developments made at the MI make them perfectly credible, even if some issues remain to be fully overcome (high intensity beam parameters and losses in the MI).

The NuMI goal of losing less than 10^{-4} along the beam line to prevent any significant activation of the machine components is certainly challenging but well prepared (beam line acceptance larger than MI acceptance, comprehensive beam diagnostics, beam permit system, gradual increase of the beam intensity during commissioning). Efficiency in reaching the goal is likely to be maximized by a thorough experimental study of the beam line optics and alignment (beam-based).

The detailed goals in terms of activation, safety, and remote handling for repair were not discussed in this meeting, but were mentioned as an essential issue for the experiment. We have to rely on the other project reviews for this issue.

Is the approach effective and is it consistent with the Run II operational plan for 2005?

The management and the preparation of the commissioning appear well organized, with a clear definition of the objectives and of the responsibilities. The sequence of tasks is defined at an appropriate level of detail. The Committee acknowledges a sound team strategy with hardware and software experts and an experimental physicist available for each commissioning shift. A solid presence of accelerator physicists is also recommended, to study in depth the beam optics and its stability.

The choice of a combined cycle for the NuMI experiment and the antiproton source suppresses any conflict with guaranteed deliveries to NuMI and the Antiproton source. The efficient magnetic shielding for the Recycler should prevent any significant cross-talk.

What are the primary technical risks and their potential impacts?

At ultimate performance with 4×10^{13} protons every 2 seconds, the beam power is 400 kW - this will be one of the highest power proton beams in the world. It was stated that a single shot is just below the level that can damage the machine. In view of recent experience at CERN with similar beams there is an incentive to systematically review and assess the possible fault conditions and damage levels.

We anticipate that any gross error (reversed/mis-calibrated/misaligned quadrupoles/magnets, BPMs,...) will be picked up at commissioning with the reduced beam intensity and will thus not represent a risk. However, the tight beam loss budget makes the experiment sensitive to any fault or drift of any beam line equipment, whether active (magnets, kickers) or passive (beam diagnostics):

- stability & regulation of magnets, particularly large bending magnets
- reliability, synchronization, and reproducibility of extraction kickers
- optics imperfections,
- calibration and coverage of the beam loss monitors,
- 10^{-4} tails invisible to profile monitors,...

This gives a particular importance to reliability, and to logging followed by efficient analysis and detailed follow-up of the NuMI performance.

How can the plan be improved?

The Committee makes the following suggestions that did not seem to appear in the material presented:

- Include tolerances on alignment, magnetic fields, BPM accuracy and orbit correction strategy in the analysis of the beam line aperture to identify the most critical positions where a hot spot could develop. Verify that the BLM coverage is appropriate there. Verify that the correction procedure does not generate π bumps in areas where the BPM sampling is reduced.
- Cut the beam distribution tails in the MI with scrapers/collimators prior to ejection.
- Foresee an automatic analysis and reporting of the beam and accelerator data logged on every shot.
- Consider the possibility of using this information in a feedback loop to cope with trajectory drifts.
- Associate accelerator physicists with the beam-line commissioning with the same quality of effort as at the Tevatron

Superconducting Module and Test Facility (SMTF) Proposal

Overall the Committee strongly supports the establishment of a Superconducting Module & Test Facility at Fermilab to develop high gradient superconducting cryomodules for the ILC and develop SCRF technology for a possible future Proton Driver. The Committee also supports the facts that such a facility is planned to be able to test strings of cavity modules with ILC-type beam, and that the development of the facility draws as much as possible on the existing expertise and infrastructure for SCRF technology at other laboratories in the US as well as world-wide.

Are the goals of the SMTF clearly established and do they make sense in terms of the needs of the U.S. based SCRF community?

The stated goal of the SMTF facility is to strengthen the capabilities of US laboratories in high gradient and high-Q superconducting accelerating structures and related subsystems. This should support the International Linear Collider and other accelerator projects in which US laboratories are interested. Many projects that rely on superconducting linac technology are mentioned explicitly in the EOI – the Proton Driver, the Rare Isotope Accelerator, the CEBAF upgrade, the JLAB-FEL, JLAB's ELIC, SNS, electron cooling for RHIC, E-RHIC, and fourth generation light sources.

Since much of the recent progress in high-gradient superconducting RF technology has been made abroad, the goal of strengthening the capabilities of US laboratories, universities, and industries in this area is very laudable, even though, in its technical details as well as in its collaborative details, the goals are not yet fully formulated. Also priorities among the many accelerator projects of interest have not been clearly established so far. The Committee advises that Fermilab establish those projects that are most relevant for FNAL; i.e. the ILC and PD, as clear priorities, even though it is welcome that the SMTF could be beneficial for other projects.

Since the goal is to strengthen capabilities at many US institutions, the Committee welcomes the fact that Fermilab plans to construct the SMTF by a consortium. This collaborative component of the effort should continue to be developed and extended. Contributions from DESY, KEK, and INFN are envisioned. This international collaboration should be extended and developed early on, in order to be meaningful.

Does the SMTF as described in the EOI effectively meet the needs of the ILC and Proton Driver programs?

The focus areas (development of cryomodule + beam test areas and fabrication of cryomodules) and stated goals (including tests with beam) are essential for demonstrating that many of the RF-related requirements for the ILC and PD projects can be fulfilled. Successful completion of the stated goals, including long-term tests and cooperation with industry, should validate the feasibility of each project.

As the proposed implementation strategies of the SMTF are developed further, the Committee would like to offer a few suggestions:

1. FNAL should define very clearly their perspective on the level of expertise in SCRF technology to be developed at FNAL (*e.g.* SCRF cavity processing at FNAL may neither be of immediate interest nor realistic on the time scale of the EOI)
2. The concept of pursuing the ILC and PD “in parallel” should be critically reviewed – clear definition of priorities and timelines by management are recommended, particularly in case of resource constraints
3. While alluded to in the EOI, the concept of working with industrial partners needs further clarification. We remark that the optimal approach will likely be different for each project component. In each case an optimum between involving industry too early, and not early enough, must be considered
4. It is critical that complete systems be brought successfully into operation; specifically, special care should be taken to ensure that no vital subsystems or requirements of such subsystems (*e.g.* low-level rf control aspects) are overlooked

The experimental program for fabrication and tests at 1.3 GHz, outlined in section 5 of the EOI, while aggressive, should be realizable on the time-scales proposed provided that adequate funding and manpower are made available. For phase 1a) detailed planning is well underway. For phase 1b) the Committee, while concurring that beam tests are highly desirable, recommends that the motivation for testing of superconducting technologies with beam be further elaborated. Furthermore, given that many of the beam tests have been performed (if not to completion) at the TESLA Test Facility, clear definitions of the measurement program and its goals are warranted. Regarding phases 2 and 3 with additional US-built cryomodules, the Committee would like to emphasize the importance of long-term operation at full gradient (35 MV/m) for the ILC project.

Care should be taken not to compromise the operating gradients in favour of shorter-term project goals.

For the PD the goals are clearly defined. Not explicitly mentioned, but considered by the Committee to be of high priority, are the near-term validation tests of the fast phase shifters. With respect to the SMTF, the PD will benefit from both main installations (at 1.3 GHz and 325 MHz):

1. The goals of testing the fast phase shifter in actual operation and driving the front end linac with one klystron are very important. Demonstrating this in operation in the time frame of the SMTF, i.e., by 2008 is vital for the PD project.
2. Risk reduction through the actual operation and testing of new concepts, and through modifications of specific items, are also essential for Fermilab in order to be ready with a built-to-print, built-to-process PD project ready to spend real money in 2008-2009.
3. The beta<1 part is also very important for the PD (although, may be less critical for the project) and the presence of the SMTF will help to coalesce a collaboration among labs and industries. It will also serve in providing a considerable increase (wrt present situation) of the production of beta<1 cavities, an essential step to assess technical and time feasibility as well as production costs for the PD.

Does the SMTF as described in the EOI effectively meet the needs of the CW SCRF communities?

The SMTF as described in the EOI addresses specific requirements for CW SCRF for applications complementary to existing programs in their bunch structure and cavity field stability requirements. Goals of demonstrating $Q_0 > 3 \times 10^{10}$, and $Q_{\text{ext}} > 2.6 \times 10^7$ at an accelerating gradient of 20 MV/m are consistent with other projects, such as the RHIC demonstration ERL for electron cooling and the Cornell x-ray ERL, which also strive for high gradient and high unloaded Q. External Q values exceeding 2.5×10^7 are also sought, for example, by the TJNAF CEBAF 12 GeV energy upgrade program. The amplitude stability of 10^{-4} and phase stability of 0.01° at 1.3 GHz for 1 nC bunches at 10 kHz bunch repetition frequency are ambitious. However, these parameters are only peripheral to what the Committee perceives as Fermilab's main interest in the SMTF concept.

The Committee is supportive of these extended goals as a possible future application for the SMTF test facility. Construction and beam tests of CW cryo-modules are motivated by light source facilities, which to some extent have parameters that have yet to be defined. Specific designs for such facilities will evolve as projects are developed. The particular aspects of developing the CW SCRF technology (such as high-Q, and high gradient) are, for the most part, being addressed at existing facilities.

Does the plan integrate well the capabilities of all participating institutions with minimal redundancy.

Preparation of the SMTF EOI (on which a proposal will be based) involved discussions among 13 U.S. national laboratories and universities, as well as 3 institutions in Europe and Japan. Presentations to the Committee included representation from 3 of the U.S. institutions - Fermilab, the University of Pennsylvania, and LBNL. While the EOI includes some useful information concerning the capabilities of the participating institutions, this information was not

presented to the Committee in a complete and systematic fashion. This makes it difficult for the Committee to assess the capabilities of the participating institutions or to evaluate whether the plan is well integrated with minimal redundancy.

It is also the opinion of the Committee that, while some redundancy is unavoidable, a certain degree of duplication and competition is healthy for science.

The Committee notes that the synergy between PD and RIA would be more effective if the SMTF is immediately launched; the synergy will become less important if time elapses with no action taken.

Is the staging plan credible?

The Committee reviewed the project phases within the EOI and was presented with a basic staging plan for implementing the first phase of the facility. This staging plan consists of early preparation work of the Meson building, some of which has already been started, followed by additional upgrades required for the SMTF such as the addition of 1.3 GHz rf power. Concurrent with this work, Fermilab plans to barter one TESLA cryomodule for a Fermilab produced 3rd harmonic SCRF cavity. This TESLA cryomodule will be used as the initial basis of the ILC test area. During this early phase the A0 photo-injector will also be moved to the Meson building and coupled to the new cryomodule. This will provide the capability of performing SCRF testing with realistic ILC beams. Preparation work for the proton driver front-end test area will also be started. Given appropriate resources, as presented in detail by P. Czarapata, this early staging plan seems credible.

The Committee was not provided with enough further detailed information regarding the later staging plan to comment on its credibility.

As a final comment the Committee would like to remark that, to meet the main goals of the SMTF, a robust injection of resources are needed. Fermilab must have strong support from the DOE if both goals of building the cryomodules (including design, R&D, etc.) and of providing the test bed are to be pursued at the same time.

Appendix

Fermilab Accelerator Advisory Committee

November 17-19, 2004 Meeting

Charge (Draft Rev. 3)

Major goals in the Tevatron complex in FY2005, in addition to continuing collider operations, include commissioning of the newly installed electron cooling system in the Recycler Ring and initiation of NuMI operations simultaneous with antiproton production in support of the Tevatron Collider. In parallel plans are progressing for aligning Fermilab's R&D activities with the vision presented in the Fermilab Long Range Plan and with the recent linear collider technology decision..

At its fall 2004 meeting the Fermilab Accelerator Advisory Committee (AAC) is asked to review, comment on, and offer recommendations as appropriate in the following areas:

1. Electron Cooling Commissioning Plan: An electron cooling commissioning plan has been prepared and reviewed internally within the Accelerator Division. The primary feedback we would like from the AAC is whether, in your view, the commissioning plan provides a sound basis for demonstrating the ability of the Recycler based electron cooling system to demonstrate cooling of antiprotons by the start of the 2005 shutdown (currently scheduled for August 2005). More specifically:
 - Are the goals well defined and credible?
 - Does the strategy appear effective both in terms of achieving these goals and in being consistent with the anticipated allocation of antiprotons and access time within the Run II plan for 2005?
 - What are the primary technical risks and their potential impacts? Are there any suggestions on mitigation of these risks?
2. NuMI Commissioning Plan: This plan is in preparation for release prior to the December 2005 accelerator startup. At this stage of preparation we would like the Committee's views on:
 - Are the goals well defined and credible?
 - Is the approach effective and is it consistent with the Run II operational plan for 2005?
 - What are the primary technical risks and their potential impacts?
 - How can the plan be improved?
3. Superconducting Module Test Facility Proposal: The laboratory has received an Expression of Interest for the construction and operation of a Superconducting Module Test Facility in support of the International Linear Collider, the Proton Driver, both of direct interest to

Report of the Fermilab AAC November 2004

Fermilab, and other superconducting rf based programs of interest within the DOE and NSF. While a more formal proposal is now in preparation by the proponents, the EOI already contains an outline of the scope, goals, and implementation strategy of the SMTF. The EOI will be presented to the AAC and we are asking for both an overall reaction to the approach accompanied by specific commentary in the following areas:

- Are the goals of the SMTF clearly established and do they make sense in terms of the needs of the U.S. based SCRF community?
- Does the SMTF as described in the EOI effectively meet the needs of the ILC and Proton Driver programs?
- Does the SMTF as described in the EOI effectively meet the needs of the CW SCRF communities?
- Does the plan integrate well the capabilities of all participating institutions with minimal redundancy.
- Is the staging plan credible?

As usual the Committee is invited to issue comments or suggestions on any aspect of the programs discussed beyond those specifically included in this charge. It is requested that a concise report responsive to this charge be forwarded to the Fermilab Director by December 17, 2004. Thank you.

Fermilab Accelerator Advisory Committee

Agenda

November 17-19, 2004
Comitium, Wilson Hall 2SE
Revision 22-Oct-2004

Wednesday, November 17

8:30-8:50	Committee Executive Session	T. Roser
8:50-9:00	Welcome and Presentation of Charge	S. Holmes

Electron Cooling Commissioning (Organized by Sergei Nagaitsev)

9:00-9:45	Overview of electron cooling scenario, commissioning plan, and schedule	S. Nagaitsev
9:45-10:15	Recycler start-up plan	C. Gattuso
10:15-10:35	Break	
10:35-11:05	Electron beam commissioning plan	A. Shemyakin
11:05-11:30	Discussion	

NuMI Commissioning (Organized by Bruce Baller)

11:30-11:45	NuMI Project Overview	G. Bock
11:45-12:00	Technical Component Status	B. Baller
12:00-1:00	Lunch	

Tour

1:00-2:00	Sites: MI-30/31 and NuMI/MINOS underground	
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NuMI Commissioning (Continued)

2:00-2:30	NuMI Commissioning for CD-4	B. Baller
2:30-3:00	Main Injector Commissioning for NuMI	A. Marchionni
3:00-3:15	Discussion	
3:15-3:35	Break	

Superconducting Module Test Facility (Organized by Bob Kephart)

3:35-4:00	Introduction to the SMTF EOI	N. Lockyer
4:00-4:40	ILC R&D at Fermilab and the SMTF plan	S. Mishra
4:40-5:00	Discussion	

5:00-6:30	Committee Executive Session.	
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Requests for supplementary or breakout presentations on Thursday

7:00	Dinner	
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Report of the Fermilab AAC November 2004

Thursday, November 18

Superconducting Module Test Facility (Continued)

8:30-9:10	Proton Driver R&D and the SMTF plan	G.W. Foster
9:10-9:40	CW Possibilities at SMTF	J. Corlett
9:40-10:00	SMTF Physical Layout and Near-term Plans	P. Czarapata
10:00-10:15	Discussion	
10:15-10:30	Break	
10:30-12:00	Supplementary presentations and/or breakout discussions as requested by the Committee. Committee Executive Session	
12:00-1:00	Lunch	
1:00-5:00	Supplementary presentations and/or breakout discussions as requested by the Committee. Committee Executive Session	

Friday, November 19

8:30-11:00	Committee Executive Session
11:00-12:00	Closeout
12:00	Adjourn